Appledore Marine Engineering, LLC

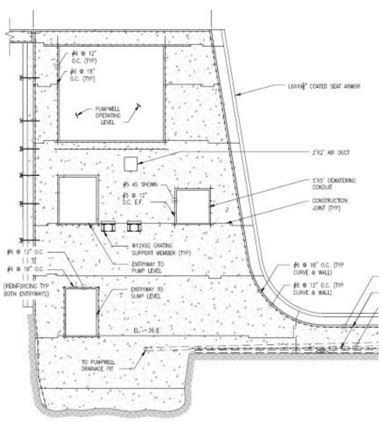
SIMCO

PORTSMOUTH NAVAL SHIPYARD – DRY DOCK 3

SIMCO PROJECT No. SIMCO15026

CONCRETE CHARACTERIZATION AND SERVICE-LIFE ASSESSMENT OF REINFORCED CONCRETE

May 20th, 2016



Status / REV	Reason for issue	Phase 1 Author	Phase 2 Authors	Revised, approved and submitted by
FINAL	Final version for client's comments.	Patrick Power, Eng., M.Sc. OIQ : 5040095	Florence Boivin-Dutil, Jr. Eng. OIQ : 5056398 Eric Ouellet, Eng., M.Sc. OIQ : 115505	Eric Ouellet, Eng., M.Sc. OIQ : 115505

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Figure 11 – Concrete repair at top of core F13

4.2 Compressive strength

The compressive strength was determined in accordance with ASTM C 42 - *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. Except for Test 1 on core F13, the sampled concrete for this test was taken at least 18 in. below the surface of the core. The results are summarized in Table 3.

Table 3 – Compressive strength results

Zone	Core ID	Compressive strength (psi)		
		Test 1	Test 2	Average
Seat Floor	F3	6,810	6,820	**6,815**
North Wall	W6	3,000	-	**-**
	W8A	5,150	-	**-**
South Wall	W10A	3,890	-	**-**
Floor	F6	6,160	-	**-**
	F13	5,845	8,035	**6,940**
	F19	2,460	-	**-**

The range of expected compressive strength for matured 0.45 portland cement concrete is 4,000 to 5,000 psi for air-entrained concrete and 5,000 to 6,000 psi for non air-entrained concrete. The results for the seat and floor concrete, except core F19, are higher than 6,000 psi or within the 5,000 to 6,000 psi range. The results from cores W6, W10A and F19 are significantly lower. A lower compressive strength could be indicative of deteriorated paste or aggregate. The result from core W8A is within the air-entrained range.

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May 6, 2016

Mr. Patrick Power
SIMCO Technologies, Inc.
2666 boul. du Parc Technologique
Suite 100
Quebec, QC Canada G1P 4S6

RE: SIMCO15026 Portsmouth Navy Shipyard Dry Dock #3
RJ Lee Group Project Number TCH508521 - Appended Report

Dear Mr. Power,

Six concrete cores from Portsmouth Navy Shipyard Dry Dock #3 were received by RJ Lee Group (RJLG) on August 12, 2015, for petrographic examination. Two additional cores were received on April 12, 2016. The samples were assigned RJLG identification numbers as seen in Table 1.

Table 1. Samples Received.

RJLG ID	Client ID	Description
3134103	F3-1	Seat 0-4.5" from surface
3134104	F3-6	Seat 30-36" from surface
3134105	W6-1	North Wall 0-6" from surface
3134106	W6-8	North Wall 71-78" from surface
3134107	F6-1	Floor 0-7" from surface
3134108	F6-5	Floor 25-34" from surface
3139260	W10A-1	South Wall 0-6" from surface
3139261	W10A-5	South Wall 24.25-30" from surface

The samples were analyzed in accordance with ASTM Method C 856 *Standard Practice for Petrographic Examination of Hardened Concrete,* and following ASTM C 1723 *Standard Guide for Examination of Hardened Concrete Using Scanning Electron Microscopy (SEM)*. After visual examination, each sample was cross sectioned and a solution of phenolphthalein, a pH indicator, was applied to one freshly cut face to determine the carbonation depth. A slab was polished for optical microscopy examination. A polished thin section 1 $^{3}/_{16}$" x 1 ¾" taken from the area of interest was prepared using fluorescent dyed epoxy for each sample. The water-cement (w/c) ratio was estimated using a combination of techniques including, but not limited to, polarized light microscopy, fluorescent light microscopy, and SEM backscattered electron microscopy.

Summary

Evidence of alkali silica reaction (ASR) of the microcrystalline and strained quartz in the metamorphic coarse aggregate was observed in each sample. The ASR products were predominately either crystalline or calcium-rich indicating that the reaction was not recent. Alkalis were still present in the ASR products indicating potential for additional reaction with water ingress. The ASR induced cracking ranged from minor amounts in Core F6 to moderate amounts in Cores W6 and W10A. Evidence of sea water intrusion was present in each surface core sample, and the interior sample of Core W6-8 at a depth of 71-78", but not in interior cores F3-6, F6-5, or W10A-5. No leaching was observed. Secondary ettringite deposits were present in voids in all samples, but no evidence of delayed ettringite formation (DEF) was observed. No evidence of cracking consistent with damage due to freeze thaw cycles was identified. Table 2 summarizes additional characteristics for each core.

Petrographic Examination

Core F3-1 (RJLG 3134103)
The core was approximately 3 ¼" in diameter and up to 4 $^{3}/_{16}$" mm long. The top surface was lightly scaled with exposed sand grains, and traces of iron corrosion product. The bottom was fractured through coarse aggregate indicating a good paste/aggregate bond with ASR gel lining voids and rimming aggregates. No steel reinforcement was observed. The core sides had entrained and entrapped air voids with trace amounts of "wet" paste rimming aggregates indicating ASR. Photographs of the core as-received are presented in Figure 1, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 2. Figure 3 presents the location of the thin section, at the top of the core to a depth of 1 ¾", on the cut face.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 27%, and the w/c ratio was estimated to be 0.45 ± 0.05. The air content was estimated at 5% and consisted of unevenly distributed entrained air voids and a trace amount of entrapped air voids with the longest at ½". The air voids were generally filled with secondary deposits throughout the thin section.

Carbonated paste with localized de-calcified paste and areas of magnesium enrichment were present up to 2 mm deep. Minor to trace amounts of secondary ettringite deposits were observed predominantly filling voids throughout the section. Moderate amounts of Friedel's salt deposits were present through depth of the thin section.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with a top size of 2 $^{1}/_{16}$" observed. The coarse aggregate showed evidence of minor ASR with micro-cracking from the aggregate into the paste. Elevated calcium content of the ASR gel present lining a void indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good condition. Representative images are presented in Figure 4 through 9.

Core F3-6 (RJLG 3134104)
The core was approximately 3 ¼" in diameter and up to 6 $^{1}/_{16}$" long. The top surface was snapped through coarse and fine aggregate with white rims around the coarse aggregate. The bottom was saw cut. No steel reinforcement was observed. The core sides had small spherical air voids with minor amounts of sub-parallel fine cracking from aggregate lined with white deposits of ASR gel. Trace amounts of white deposits of predominately ASR gel were lining voids the length of the sample. Photographs of the core as-received are presented in Figure 10, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 11. Figure 12 presents the location of the thin section on the lapped slab.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 27%, and the w/c ratio was estimated to be 0.45 ± 0.05. The air content was estimated at 2-3% and consisted of unevenly distributed small, spherical air voids and a trace amount of coarser air voids with the longest at ½”.

A trace amount of secondary ettringite deposits was observed lining cracks and voids throughout the section. No chloride ingress was observed. Localized trace amounts of carbonation was observed along the crack faces.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with a top size of 1 ¼” observed. Moderate amounts of sub-parallel fine cracking induced by ASR were observed the length of the core. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 13 through 19.

Core W6-1 (RJLG3134105)

The core was approximately 3 ¼” in diameter and up to 4 ⅝” long. The top surface was angled, formed surface with up to ¼” of calcium marine growth. The bottom was fractured through coarse aggregate indicating a good paste/aggregate bond. No steel reinforcement was observed. The core sides had entrained and entrapped air voids with trace amounts of subparallel fine cracking from aggregate lined with white deposits of ASR gel. Moderate amounts of white deposits of predominately secondary ettringite with trace amounts of ASR gel and Friedel’s salts were filling voids the length of the sample. Photographs of the core as-received are presented in Figure 20, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 21. Figure 22 presents the location of the thin section on the lapped slab.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 5-7% and consisted of well distributed entrained air voids and a trace amount of entrapped air voids with the longest at ½”. The air voids were generally filled with secondary deposits throughout the section.

Carbonation was observed up to ¼” beneath the surface. Trace amounts of magnesium oxide and calcium carbonate were present along the perpendicular crack face up to 1 ⅜”. Moderate to severe amounts of secondary ettringite deposits were observed predominantly filling voids throughout the section. Minor-moderate amounts of Friedel’s salt deposits were present throughout the section.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with a top size of 1 ½” observed. Moderate amounts of sub-parallel fine cracking induced by ASR were observed between ¾” and 3 $^{5}/_{16}$” deep. A fine crack induced by ASR and perpendicular to the angled surface extended 1 ⅜” deep. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 23 through 32.

Core W6-8 (RJLG 3134106)

The core was approximately 3 ¼" in diameter and up to 6 ⅛" long. The top surface was cut with ASR gel in cracks. The bottom was an angled formed surface with a white crystalline deposit over formed grooves and a partial snap fracture. No steel reinforcement was observed. The core sides had entrained and entrapped air voids with minor amounts of sub-parallel and perpendicular fine cracking from aggregate lined with white deposits of ASR gel. Minor-moderate amounts of white deposits of ASR gel and secondary ettringite were filling voids the length of the sample. Photographs of the core as-received are presented in Figure 33, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 34. Figure 35 presents the location of the thin section on the lapped slab.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 5-7% and consisted of well distributed entrained air voids and a trace amount of entrapped air voids with the longest ½". The air voids were generally lined or filled with secondary deposits throughout the section.

Trace to minor amount of secondary ettringite deposits were observed predominantly lining voids throughout the thin section. Trace amounts of Friedel's salt deposits were present throughout the section lining cracks and voids. Trace amounts of carbonation were observed localized along the crack faces.

The coarse aggregate consisted predominantly angular metamorphic rock (likely a mylonite) with a top size of 1 ⅛" observed. Moderate to severe ASR induced predominately perpendicular fine cracking was observed the length of the core mainly from coarse aggregate. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 36 through 45.

Core F6-1 (RJLG 3134107)

The core was approximately 3 ¼" in diameter and up to 5 ⅞" long. The top surface exhibited exposed sand grains and a rust-colored discoloration. The bottom was cut with ASR gel along the paste/aggregate interfaces. The core sides had entrained and entrapped air voids. Photographs of the core as-received are presented in Figure 46, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 47. Figure 48 presents the location of the thin section on the lapped slab.

The surface of this core exhibited variable porosity in layers, entrapped air in the top 1 mm, and entrapped bleed water channels with a discontinuous sub-parallel fine crack at $^{9}/_{16}$" - ¾" deep. The paste above this crack was more porous and had reduced air content as compared to the near surface and the concrete paste below. The general depth of surface defects was $^{13}/_{16}$". The concrete was composed of moderate to well hydrated Portland cement. The paste content was estimated at 28-29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 5-7% and consisted of well distributed entrained air voids and a trace amount of entrapped air voids with the longest at ¾". The air voids were generally filled with secondary deposits throughout the section.

Carbonation less than 2 mm deep with de-calcified grain in the top 1 mm was observed. Little to no leaching was observed. Minor to moderate amounts of secondary ettringite deposits were observed in lining cracks and voids and in the paste throughout the section. Trace amounts of Friedel's salt deposits and chloride enrichment of the paste were present throughout the section in the paste.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with minor amounts of crushed basalt with a top size of 1 ⅜" observed. The sample was slightly gap graded with localized area void of very coarse aggregate. Minor amounts of predominately sub-parallel fine cracking induced by ASR of the coarse aggregate were observed the length of the core. A fine perpendicular crack induced by ASR extended from ⅝" deep to the surface. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 49 through 59.

Core F6-5 (RJLG 3134108)

The core was approximately 3 ¼" in diameter and 5 $^{13}/_{16}$" long. The top and bottom surfaces were saw cut. No steel reinforcement was observed. The core sides had small spherical air voids. Photographs of the core as-received are presented in Figure 60, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 61. Figure 62 presents the location of the thin section on the cut face.

The concrete was composed of well hydrated Portland cement. Evidence of high temperature during curing was detected as two-toned rims in the hydrated cement. The paste content was estimated at 28-29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 2-3% and consisted of unevenly distributed small spherical air voids with the longest at ⅜". The air voids were generally filled with secondary deposits throughout the section.

Minor to moderate amounts of secondary ettringite deposits were observed predominantly lining cracks and in the paste throughout the section. No indication of expansion due to delayed ettringite formation was detected. No chloride ingress was observed. No carbonation was observed.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with minor amounts of crushed basalt with a top size of 1 $^{13}/_{16}$" observed. Minor amounts of sub-parallel and perpendicular fine cracking induced by ASR were observed the length of the core. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel in cracks and lining voids indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 63 through 72.

Core W10A-1 (RJLG 3139260)

The core was approximately 3 ⅝" in diameter and up to 5 $^{15}/_{16}$" long. The top surface exhibited exposed sand grains with localized areas of orange discoloration. The bottom was sheared through coarse aggregates with ASR gel along the paste/aggregate interfaces, coating the paste and filling or lining voids. The core sides had fine cracks from reactive coarse aggregates with ASR product lining or filling voids in minor-moderate amounts, and “wet” paste rimming the majority of the coarse aggregates. Photographs of the core as-received are presented in Figure 73, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 74. Figure 75 presents the location of the thin section on the cut face.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 7% and consisted of well distributed entrained air voids and a minor amount of entrapped air voids with the longest at ⅝”. The air voids were generally lined or filled with secondary deposits throughout the section.

Localized carbonation with trace amount of de-calcified grain up to 1 mm deep was observed. Little to no leaching was observed. Minor amounts of secondary ettringite deposits were observed filling or lining voids and in the paste throughout the section. Friedel’s salt deposits were present throughout the section lining voids in minor to moderate amounts with trace amounts in the paste.

Perpendicular micro-cracking was observed along the surface, with a localized trace amount of magnesium silicate deposit along the edge of one crack present in thin section. The crack lead to an ASR reacted coarse aggregate.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with a top size of 1 ¼” observed but with a typical size of ⅞”. Moderate amounts of predominately sub-parallel fine to micro cracking induced by ASR of the coarse aggregate were observed the length of the core. Crystalline ASR product present in the cracked aggregate, and the elevated calcium content of the ASR gel indicated that the reaction was not recent. The fine aggregate consisted of manufactured and natural sand and trace amounts of fine sized coarse aggregates.

The core was generally in fair condition. Representative images are presented in Figure 76 through 89.

Core W10A-5 (RJLG 3139261)

The core was approximately 3 $^{11}/_{16}$” in diameter and up to 5 $^{9}/_{16}$” long. The top and bottom surfaces were saw cut. No steel reinforcement was observed. The core sides had fine cracks from reactive aggregates with traces of ASR product observed in voids and “wet” paste rimming the majority of the coarse aggregates. Photographs of the core as-received are presented in Figure 90, and a photograph of the freshly cut core showing the color change after application of phenolphthalein indicator is shown in Figure 91. Figure 92 presents the location of the thin section on the cut face.

The concrete was composed of well hydrated Portland cement. The paste content was estimated at 29%, and the w/c ratio was estimated to be 0.40 ± 0.05. The air content was estimated at 7% and consisted of evenly distributed entrained air voids, and a trace amount of entrapped air with the longest at ½”.

Trace to minor amounts of secondary ettringite deposits were observed predominantly lining or filling voids and cracks and in the paste concentrated near the cracks. No indication of expansion due to delayed ettringite formation was detected. No chloride ingress was observed. No carbonation was observed.

The coarse aggregate consisted predominantly of angular metamorphic rock (likely a mylonite) with a top size of 2 $^{7}/_{16}$” observed. A gap of coarse aggregate sizes was observed as the next largest coarse aggregate had a top size of 1 ⅝". The coarse aggregate showed evidence of minor ASR with micro-cracking from the aggregate into the paste oriented sub-parallel or obliquely through depth of the core. Crystalline ASR product present in the cracked aggregate and the elevated calcium content of the ASR gel in cracks and lining voids indicated that the reaction was not recent. Additionally, ASR induced cracking in the paste was often filled with secondary ettringite deposits. The fine aggregate consisted of manufactured sand and trace amounts of mica, opaques and fine sized coarse aggregates.

The core was generally in good-fair condition. Representative images are presented in Figure 92 through 103.

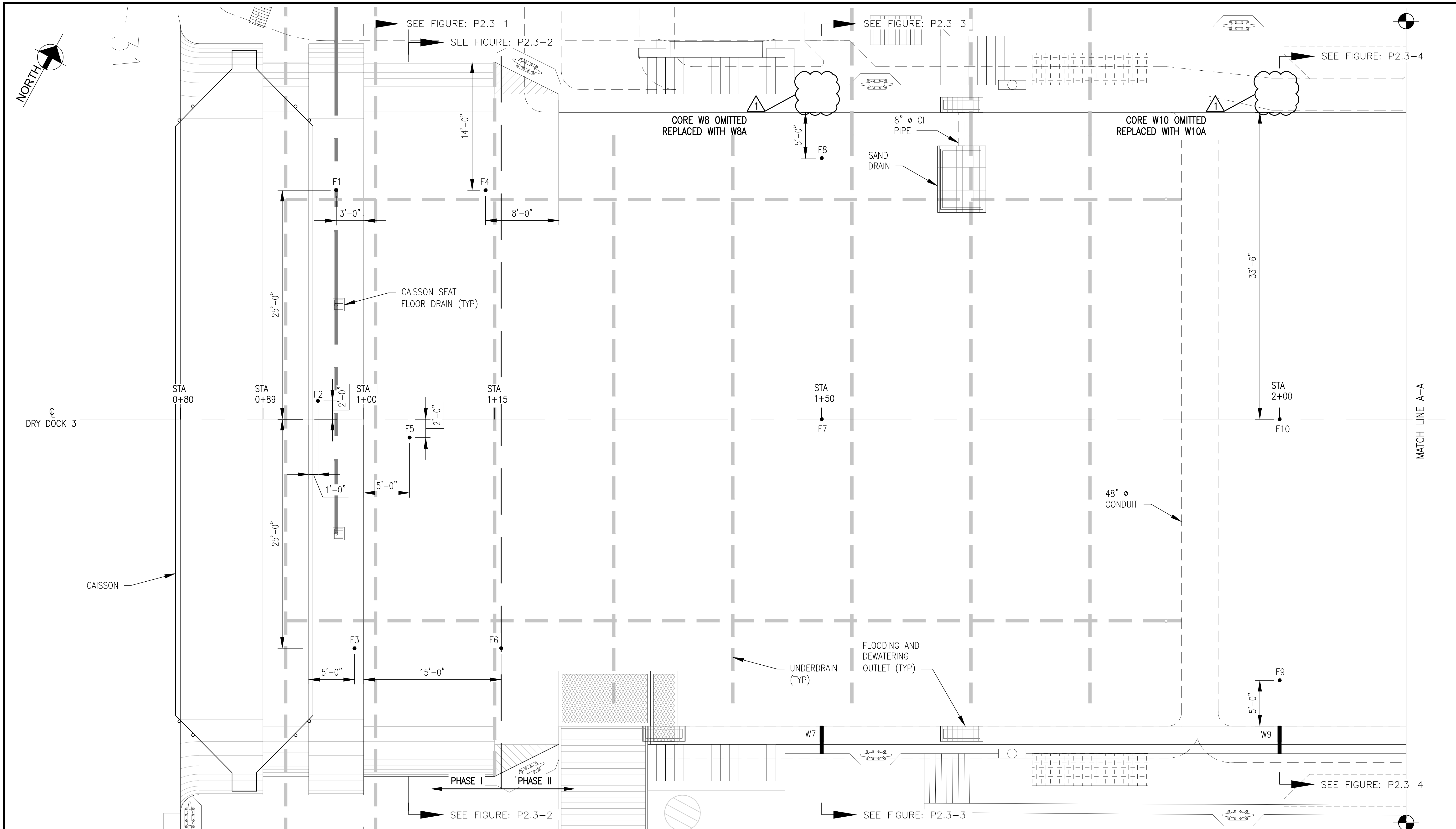
These results are submitted pursuant to RJ Lee Group's current terms and conditions of sale, including the company's standard warranty and limitation of liability provisions. No responsibility or liability is assumed for the manner in which the results are used or interpreted. Unless notified to return the samples covered in this report, RJ Lee Group will store them for a period of ninety (90) days before discarding.

Should you have any questions regarding this information, please do not hesitate to contact me.

Sincerely,

Patty Sue Kyslinger
Concrete Petrographer

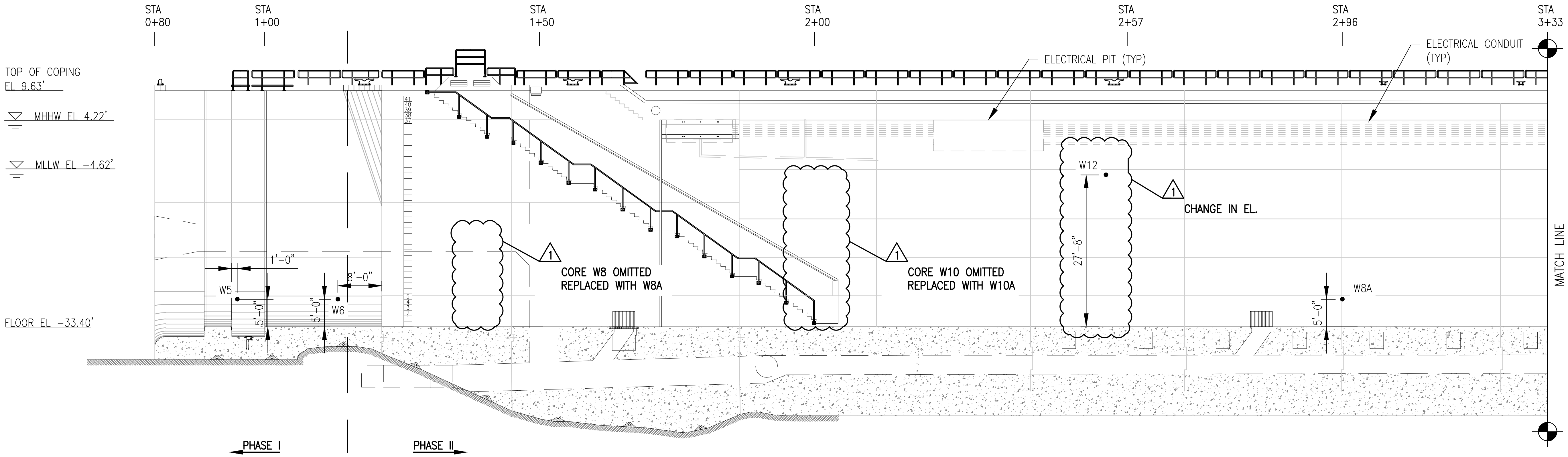
April Snyder
CM Laboratory Manager

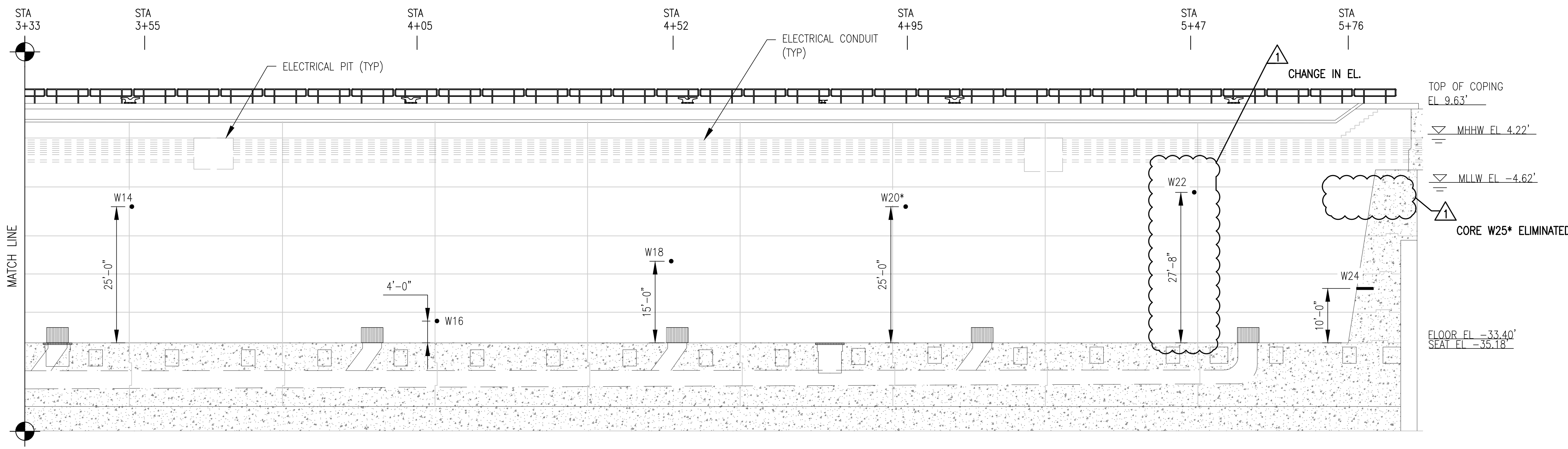


NOTES:

1. ELEVATIONS ARE IN FEET AND ARE BASED ON NAVD88.
2. DEPTH OF CORES SHOWN ARE TO BE TWO FEET IN DEPTH UNLESS OTHERWISE NOTED.
3. THOSE CORES NOTED WITH * WILL BE THREE FEET.

GRAPHIC SCALE	DATE	APPLEDORE MARINE ENGINEERING, LLC	NAVAL FACILITIES ENGINEERING COMMAND PORTSMOUTH, NEW HAMPSHIRE	
0 10' 20'	FEBRUARY 2016	PORTSMOUTH, N.H.	PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE DRY DOCK #3 CONCRETE CORING PLAN	FIG. NO. P2.1-1





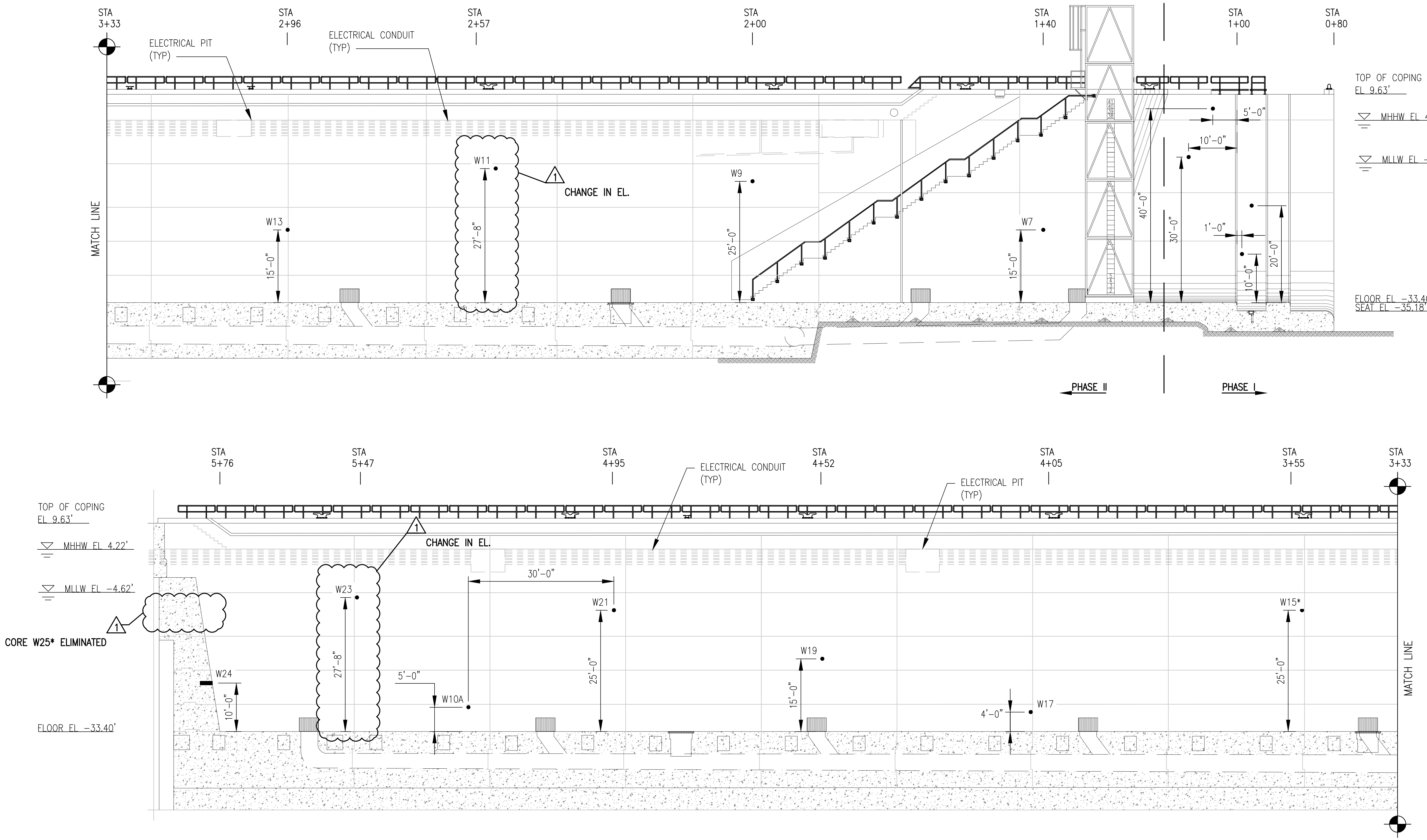
NOTES:

1. ELEVATIONS ARE IN FEET AND ARE BASED ON NAVD88.
2. DEPTH OF CORES SHOWN ARE TO BE TWO FEET IN DEPTH UNLESS OTHERWISE NOTED
3. THOSE NOTED WITH * WILL BE THREE FOOT CORES

GRAPHIC SCALE

0 10' 20' 40'

DATE	APPLEDORE MARINE ENGINEERING, LLC PORTSMOUTH, N.H.	NAVAL FACILITIES ENGINEERING COMMAND PORTSMOUTH, NEW HAMPSHIRE	
FEBRUARY 2016		PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE DRY DOCK #3 CONCRETE CORING NORTH ELEVATION	FIG. NO. P2.2-1



NOTES:

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3. THOSE CORES NOTED WITH * WILL BE THREE FEET.

GRAPHIC SCALE: 0 10' 20' 40'

DATE: FEBRUARY 2016

APPLEDORE MARINE ENGINEERING, LLC
PORTSMOUTH, N.H.

NAVAL FACILITIES ENGINEERING COMMAND
PORTSMOUTH, NEW HAMPSHIRE

PORTSMOUTH NAVAL SHIPYARD — KITTERY, MAINE

DRY DOCK #3
CONCRETE CORING SOUTH ELEVATION

FIG. NO. P2.2-2